Ozone as a control treatment for invasive species in marine ballast waters

W Stubblefield, R Gensemer, G Dethloff - *ENSR Corporation*

W Cooper – *Univ of N Carolina at Wilmington*

P Dinnel –*Western Washington University*

R Herwig, M House –*Univ of Washington*

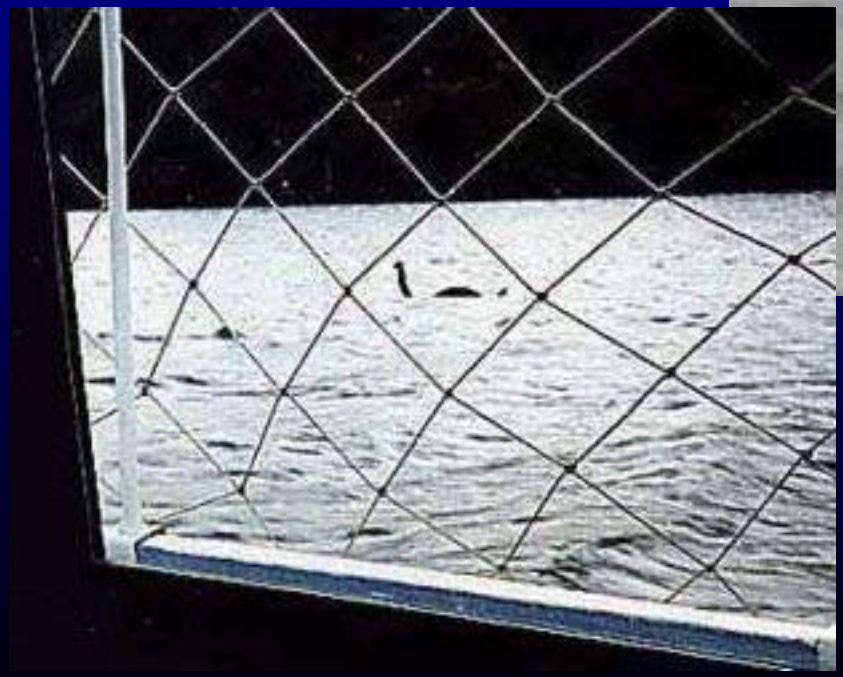
J Kopp – *Petrotechnical Resources Alaska*

G Ruiz – *Smithsonian Environmental Research Center*

E VanderWende – *BP Exploration*

Invasive species
What's the problem?

Case study:
Loch Ness



Enough said.....

What is ozone?

- Allotropic form of oxygen (O3)
- Colorless gas
- Characteristic odor
- Extremely reactive oxidizing agent

Ozone use in aquatic systems

- Disinfection
- Algal control
- Removal/reduction of odor and color causing organics
- Turbidity reduction
- Oxidation of nitrites
- Increased biodegradability of organics
- Improved coagulation of particulate matter

Primary concerns

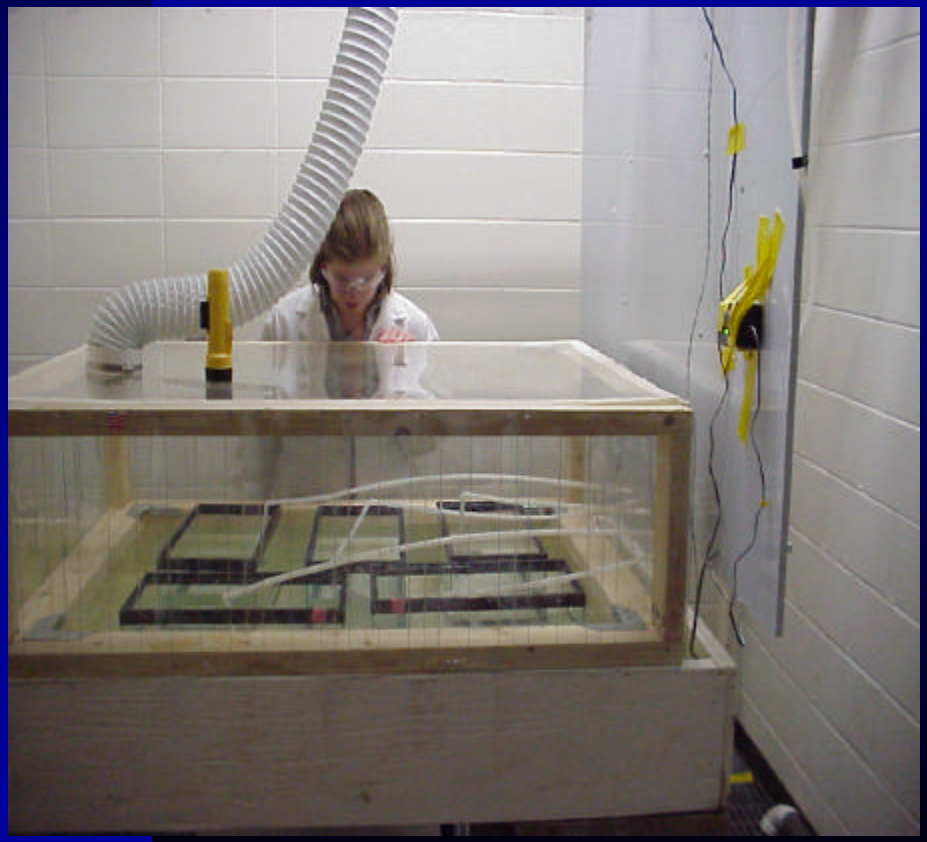
- How much ozone is required for an effective treatment?
  - Concentration
  - Exposure/contact time
  - Exposure frequency
  - Species/life stage/habitat specificity
- What residual toxicity needs to be mitigated prior to discharge?
  - Whole effluent toxicity (WET) tests

Ozone chemistry in seawater

- Reaction products
  - Ozone
  - "Reactive" products
    - Hypobromous acid (HOBr)
    - Hypobromite ion (OBr^-)
  - "Stable" products
    - Bromoform ($CHBr_3$)
    - Bromate (BrO_3^-)
- Measurement
  - Total Residual Oxidants (TRO)
  - Oxidation:Reduction Potential (ORP)

Two phased research approach

Laboratory



Field

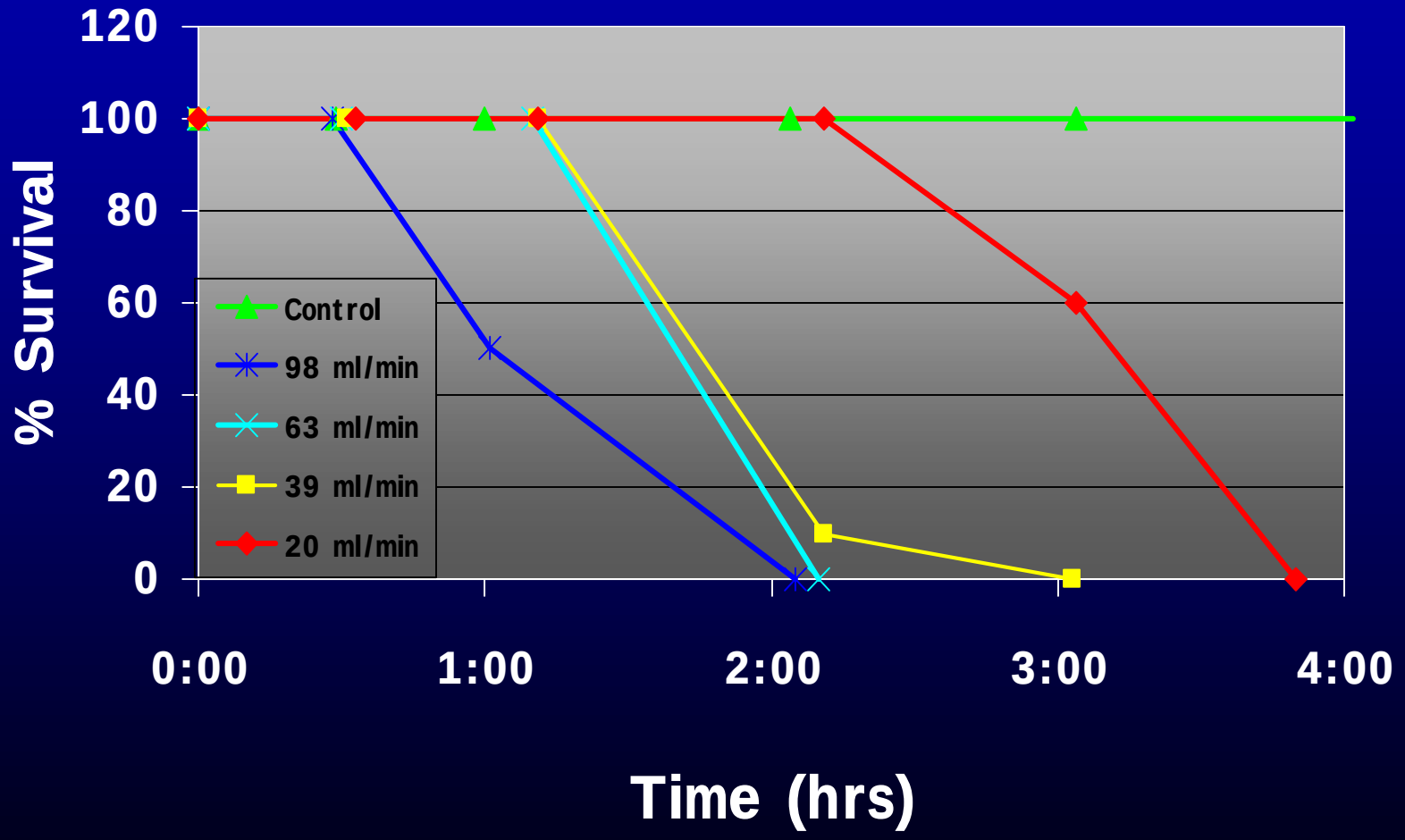
Laboratory testing program

- Determine the relationship between the exposure concentration and the time of exposure
- Determine a range of species sensitivity
  - Bacteria → fish

Laboratory testing program

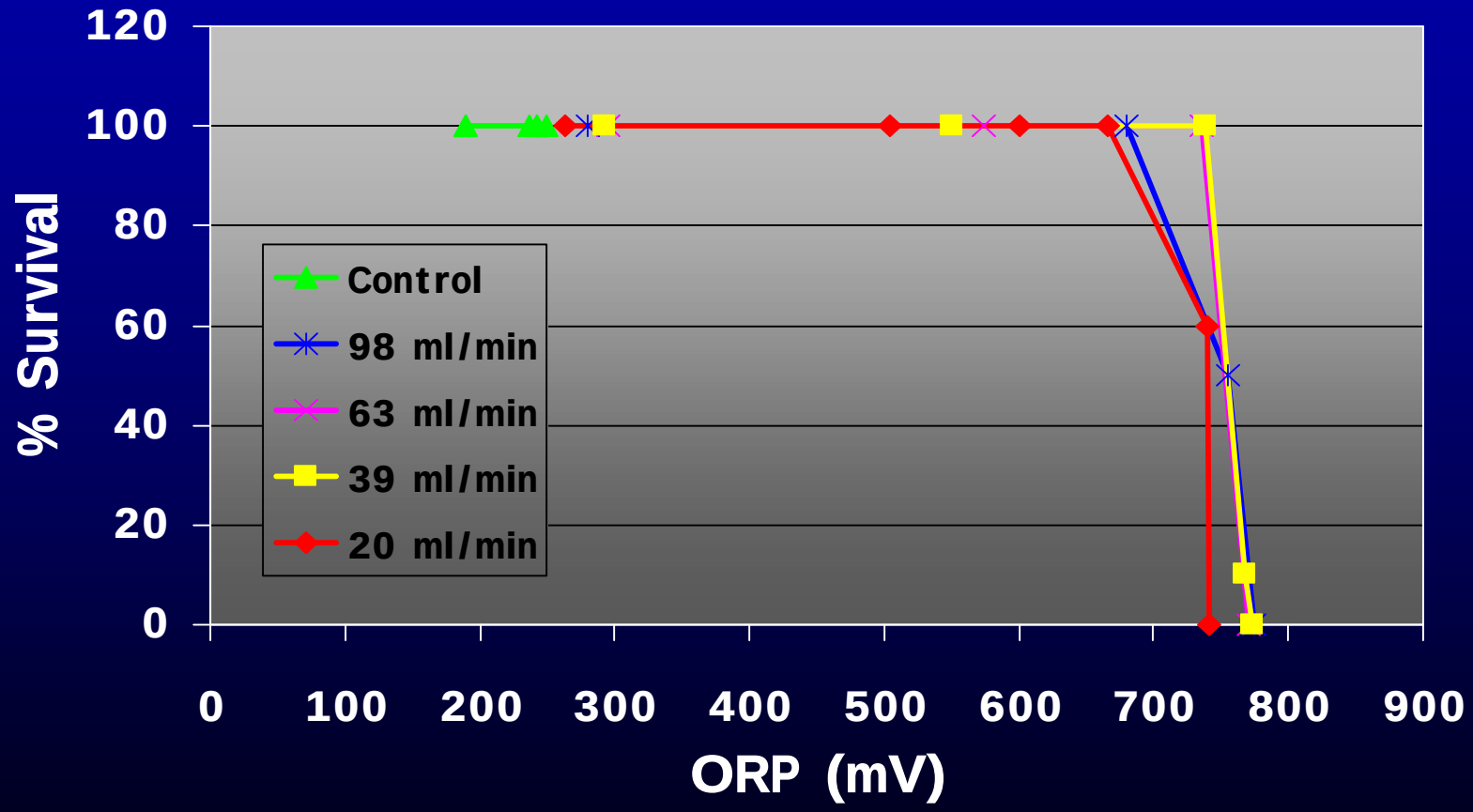
- Determine factors that may effect exposure concentrations
  - Flocculent additives
  - Salinity
  - Organic carbon load
  - Suspended solids
  - Temperature

Sheepshead minnow survival vs. time



O_3 concentration: 0.07 mg O_3/ml

Sheepshead minnow survival vs. ORP concentration



O_3concentration: 0.07 mg O_3/ml

TV Tonsina
Alaska Tanker Company, LLC

- Double-hull tanker
- 869’ long x 136’ beam
- Cargo capacity 807,000 bbls
  - 12 cargo tanks (~2,800,000 gal/tank)
- Ballast capacity 269,520 bbls
  - 12 ballast tanks (~850,000 gal/tank)

Ozone generation system

- Generates 1,800 g/O_3/h
- Distributed through a series of ceramic diffusers in each ballast tank

Field testing program

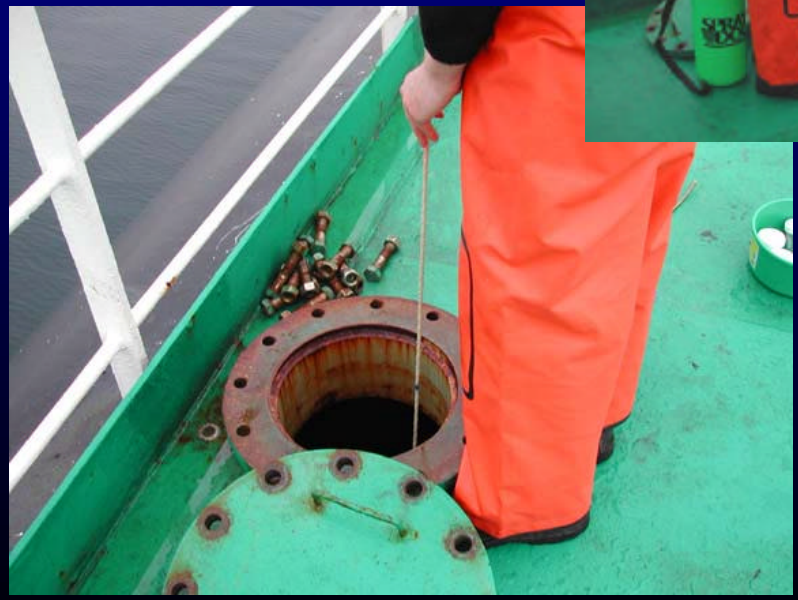
- Evaluate the efficacy of O_3 as a control agent under field conditions
  - Exposure
    - Concentration of O_3 products
    - Spatial and temporal heterogeneity
  - Effects
    - Examine the toxicity of O_3 to a range of organisms under field conditions

Field testing program

- Exposure measures
  - Niskin bottle samples
  - TRO/ORP/Bromate/ Bromoform concentrations
  - Examine spatial heterogeneity

Field testing program

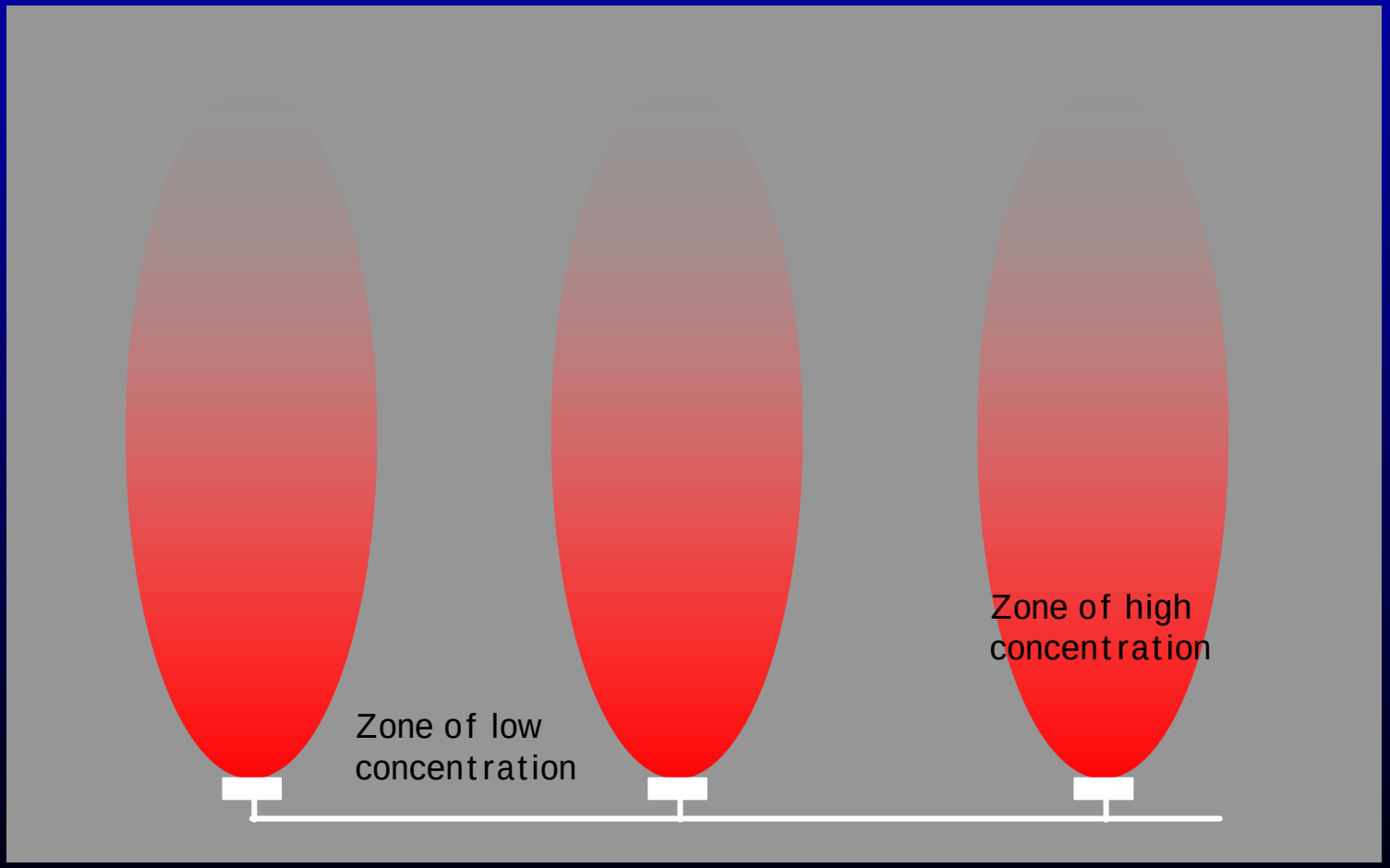
- Effects measures
  - Bacterial counts
  - Plankton tows



Field testing program

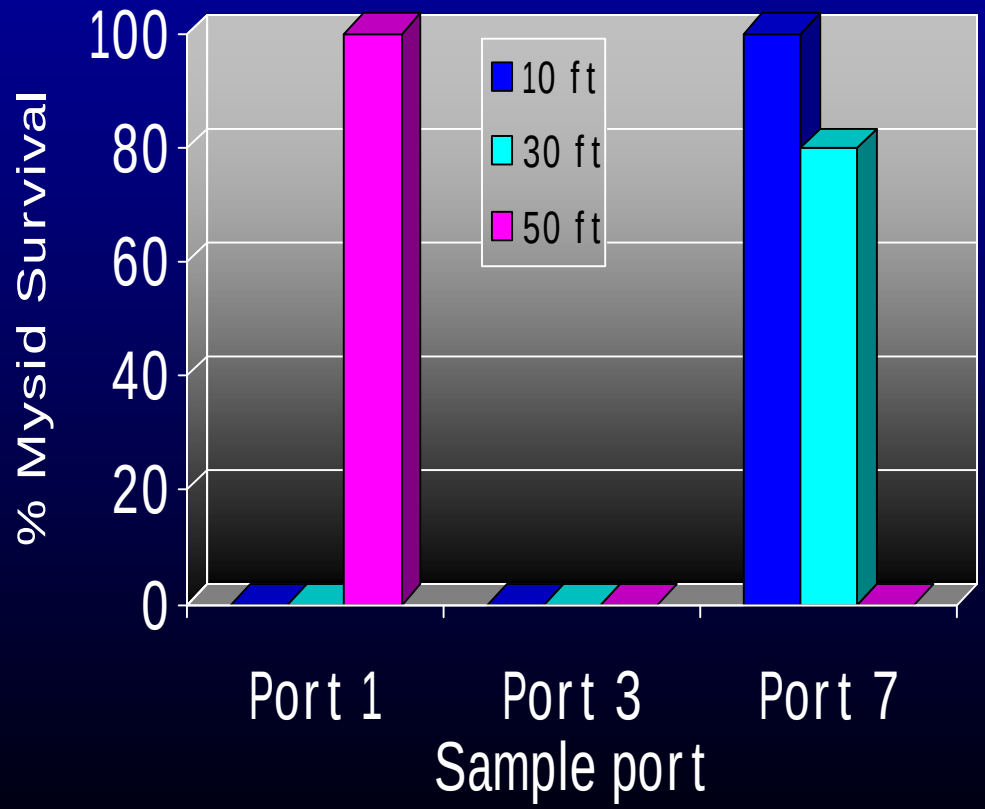
- Effects measures
  - *In situ* toxicity tests
    - Benthic sediment
      - *Rhepoxynius abronius*
    - Water-column cages
      - Mysid shrimp
      - Sheepshead minnows
      - Shore crabs

Exposure is an important consideration



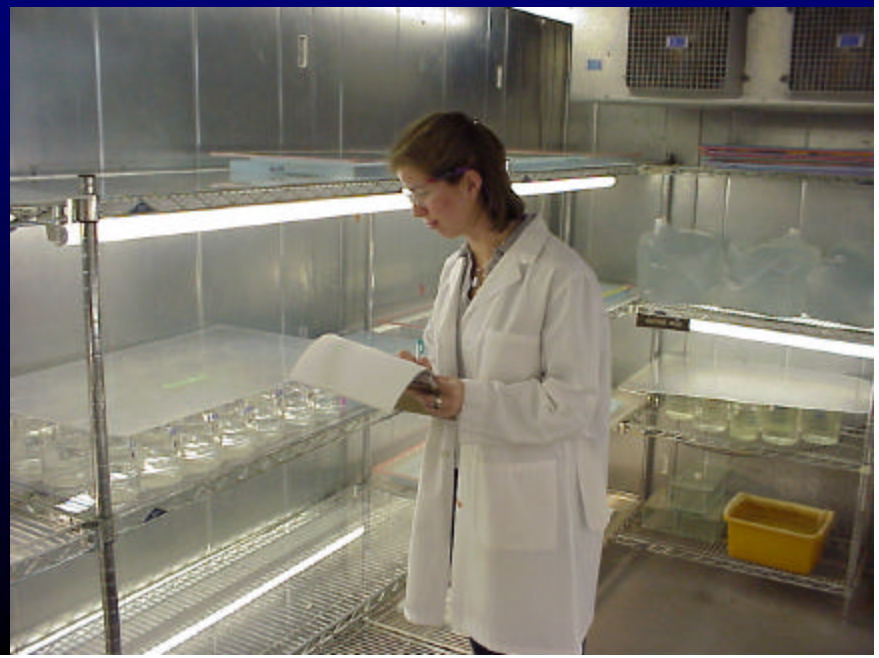
Organism survival varied with species and tank position following 10hr O_3 exposure

- Plankton & bacteria showed high mortality
- Mysid survival varied with depth
- Sheepshead minnows died at all depths
- Shore crabs and benthic invertebrates unaffected



WET testing

- Effluent discharges require testing to ensure no adverse effects on organisms in the receiving waters
  - Chemical specific parameters
  - WET testing
    - Acute
      - Mysid shrimp
      - Topsmelt
    - Chronic
      - Echinoderm or mollusk embryo/larval



Conclusions

- Evaluation of any ballast water treatment technology should include both laboratory tests and field validation
- Evaluation of chemical control agents must include an assessment of exposure concentration and duration, efficacy, and residual toxicity

Conclusions

- Ozone is an effective agent for the control of a variety of aquatic organisms in ballast waters although there is variability due to species sensitivity and O_3 distribution
- Post-ozonation residual toxicity of ballast waters is low